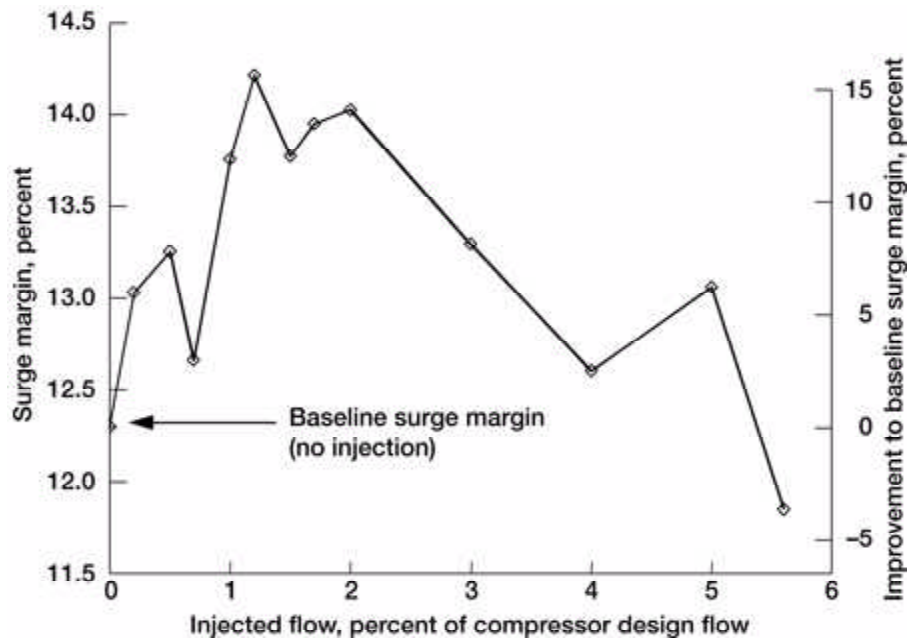


# Centrifugal Compressor Surge Margin Improved With Diffuser Hub Surface Air Injection

Aerodynamic stability is an important parameter in the design of compressors for aircraft gas turbine engines. Compression system instabilities can cause compressor surge, which may lead to the loss of an aircraft. As a result, engine designers include a margin of safety between the operating line of the engine and the stability limit line of the compressor. The margin of safety is typically referred to as "surge margin." Achieving the highest possible level of surge margin while meeting design point performance objectives is the goal of the compressor designer. However, performance goals often must be compromised in order to achieve adequate levels of surge margin. Techniques to improve surge margin will permit more aggressive compressor designs.



*Surge margin improvement with injection that was bisected by the vane in a 4:1 pressure ratio centrifugal compressor at 100 percent of the design speed,*

$$\text{Surge margin} = \frac{pr_{\text{surge}} \text{ mass-flow}_{\text{ref}}}{pr_{\text{ref}} \text{ mass-flow}_{\text{surge}}}$$

Centrifugal compressor surge margin improvement was demonstrated at the NASA Glenn Research Center by injecting air into the vaned diffuser of a 4:1-pressure-ratio centrifugal compressor. Tests were performed using injector nozzles located on the diffuser hub surface of a vane-island diffuser in the vaneless region between the impeller trailing edge and the diffuser-vane leading edge. The nozzle flow path and discharge shape were

designed to produce an air stream that remained tangent to the hub surface as it traveled into the diffuser passage. Injector nozzles were located near the leading edge of 23 of the 24 diffuser vanes. One passage did not contain an injector so that instrumentation located in that passage would be preserved. Several orientations of the injected stream relative to the diffuser vane leading edge were tested over a range of injected flow rates. Only steady flow (nonpulsed) air injection was tested.

At 100 percent of the design speed, a 15-percent improvement in the baseline surge margin was achieved with a nozzle orientation that produced a jet that was bisected by the diffuser vane leading edge. Other orientations also improved the baseline surge margin. Tests were conducted at speeds below the design speed, and similar results were obtained. In most cases, the greatest improvement in surge margin occurred at fairly low levels of injected flow rate.

Externally supplied injection air was used in these experiments. However, the injected flow rates that provided the greatest benefit could be produced using injection air that is recirculating between the diffuser discharge and nozzles located in the diffuser vaneless region. Future experiments will evaluate the effectiveness of recirculating air injection.

## Reference

1. Suder, K.L., et al.: Compressor Stability Enhancement Using Discrete Tip Injection. ASME J. Turbomachinery, vol. 123, no. 1, 2001, pp. 14-23.

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